

Development of a Calibrated Watershed Model, Potomac River Basin

*A Cooperative Project between the U.S. Geological Survey (USGS),
the Interstate Commission on the Potomac River Basin (ICPRB),
the Maryland Department of the Environment (MDE), and the
U.S. Environmental Protection Agency Chesapeake Bay Program Office (CBP)*

Progress Report

October 1–December 31, 2002

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Project Description

Problem. Work performed by the National Water-Quality Assessment (NAWQA) Program Potomac River Basin study unit (1992-95) indicated that elevated concentrations of nutrients in surface and ground water in the basin often result from human activities such as manure and fertilizer application. A watershed model of the basin is needed to assess the effects of point and nonpoint nutrient and sediment sources on water quality in the Potomac River and its tributaries.

Objectives. The USGS is responsible for the following objectives: 1) compile necessary data for simulation of Potomac watershed processes, using the Hydrologic Simulation Program-FORTRAN (HSPF); 2) create necessary control files for HSPF simulation of the Potomac River Basin, following the framework developed by CBP for Phase 5 of the Chesapeake Bay Watershed Model (CBWM); 3) develop and implement innovative calibration procedures to improve HSPF model calibration; 4) calibrate an HSPF model for the Potomac River Basin; and 5) prepare reports on calibration and analysis of model results.

Benefits and relevance. The calibrated Potomac Watershed Model will allow resource managers to simulate the effects of land-use changes and best management practices on water quality and evaluate alternative approaches for correcting existing water-quality and water-quantity problems within the Potomac River Basin. The proposed study also meets several goals of the USGS Water Resources Division (WRD).

Approach and methods. The proposed study will involve the following tasks: 1) compilation of existing input data, development of model segmentation and network, processing of time-series data, and compilation of ancillary data and observational data for model calibration; 2) development of a model calibration strategy through implementation of existing software for general inversion and calibration of multi-parameter hydrological models; 3) calibration of hydrological and water-quality model (sediment and nutrients); 4) analysis of model results, including consideration of specific study questions; and 5) dissemination of calibrated model and preparation of final reports analyzing the model results.

Progress During Reporting Period

During the past 3 months, the following tasks were completed by the USGS:

1. The regional geomorphic regression analysis was completed for three regions (Piedmont, Appalachian Highlands, and Valley and Ridge) within the Potomac Basin.
2. A methodology for the calculation of floodplain slope for each USGS stream-gaging station from stream cross sections was developed.
3. Estimation of channel roughness using Manning's equation was evaluated.
4. Data from the new precipitation model was tested against the rainfall model from USEPA Chesapeake Bay Program Watershed Model phase 4.3. A comparison of monthly and annual precipitation was developed using the two models and the observed data in the Gunpowder Basin.

Regional Geomorphic Regression Analysis (Doug Moyer, USGS, Richmond, and Mick Senus, USGS, Baltimore)

Collection of cross sections information for the generation of FTABLES was completed for three geomorphic regions within the Potomac Basin. Information came from the indirect measurements USGS files, MDE data, and the report "Maryland Stream Survey: Bankfull Discharge and Channel Characteristics of Streams in the Piedmont Hydrologic Region", March 2002, US Fish & Wildlife Service, CBFO-S02-01. This information was used to produce regressions on the following parameters as a function of the drainage area: (1) bankfull width (

Figure 1), (2) bankfull height (

Figure 2), and (3) bottom width (Figure 3). Values of r^2 for the regressions (Table 1) varied between 0.63 and 0.93. For the development of these regressions a trapezoidal channel was assumed.

Table 1. Correlation coefficients (r^2) from regional geomorphic regressions.

Appalachian Highlands	
Bottom width vs. drainage area	0.78
Bankfull high vs. drainage area	0.63
Bankfull width vs. drainage area	0.88
Bankfull discharge vs. drainage area	0.93

Valley and Ridge	
Bottom width vs. drainage area	0.85
Bankfull high vs. drainage area	0.7
Bankfull width vs. drainage area	0.84
Bankfull discharge vs. drainage area	0.83

Piedmont	
Bottom width vs. drainage area	0.89
Bankfull high vs. drainage area	0.79
Bankfull width vs. drainage area	0.93
Bankfull discharge vs. drainage area	0.85

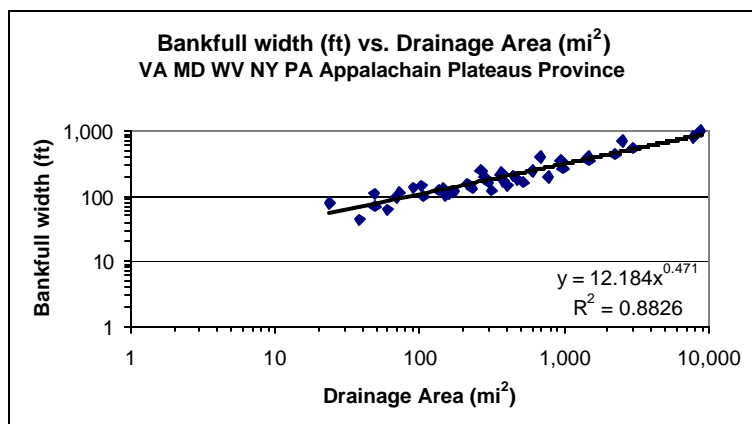


Figure 1. Bankfull width as a function of the drainage area.

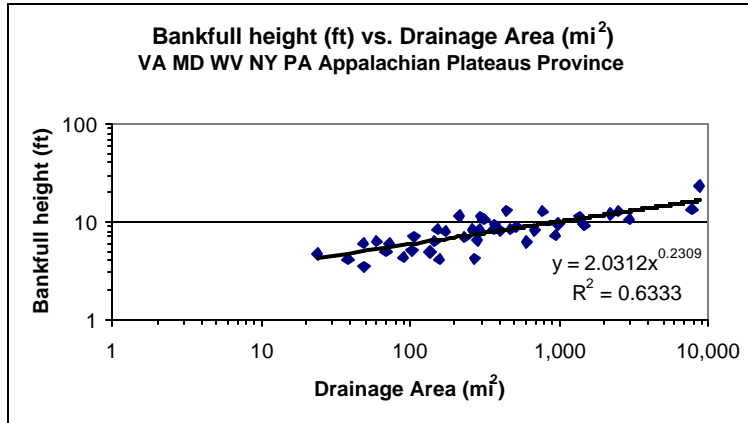


Figure 2. Bankfull height as a function of the drainage area.

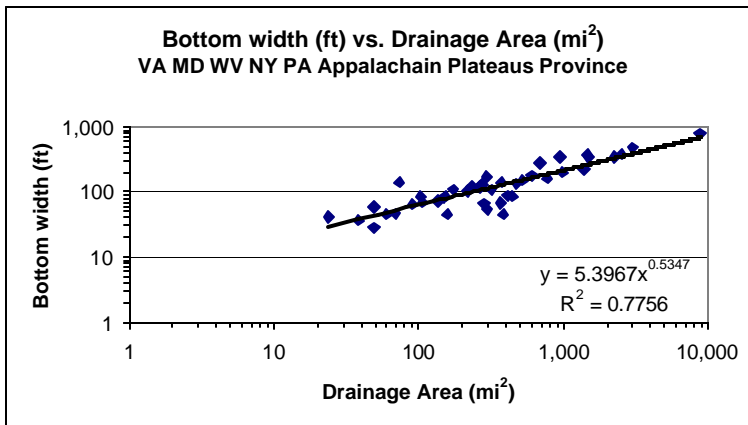


Figure 3. Bottom width as a function of the drainage area.

Flood Plain Slopes

Flood plain slopes were developed through GIS methodologies and information. For the Potomac Basin, slopes varied between 0% and 20% .

Estimation of Stream Roughness Coefficient

The bankfull discharge equation was evaluated for the estimation of the stream roughness coefficient. A transformation shown in equation (1) was proposed to be used throughout the watershed:

$$Q_{bkf} = V_{bkf} A_{bkf} \quad 1$$

The transformation is shown below:

$$n_{bkf} = \frac{1}{Q_{bkf}} (1.49 R^{2/3} S^{1/2} A_{bkf}) \quad 2$$

Precipitation Model

The Potomac precipitation model spatially distributes recorded point-precipitation data to provide high-resolution, low-bias areal precipitation time-series data at an hourly time step for use as input to hydrologic models.

An HSPF application in the Gunpowder Basin was used to test the data from the Potomac precipitation model against recorded hourly rainfall data from the NOAA station 185934, and data from the USEPA Chesapeake Bay Program Watershed Model phase 4.3. The hydrological application in the Gunpowder Basin was calibrated using point data from the NOAA station. The tests were performed for the calendar years 1995, 1996, and 1997. When comparing annual precipitation depths, the Potomac Model (phase 5) values were closer to the annual recorded rainfall than values from the phase 4.3 precipitation model Figure 4.

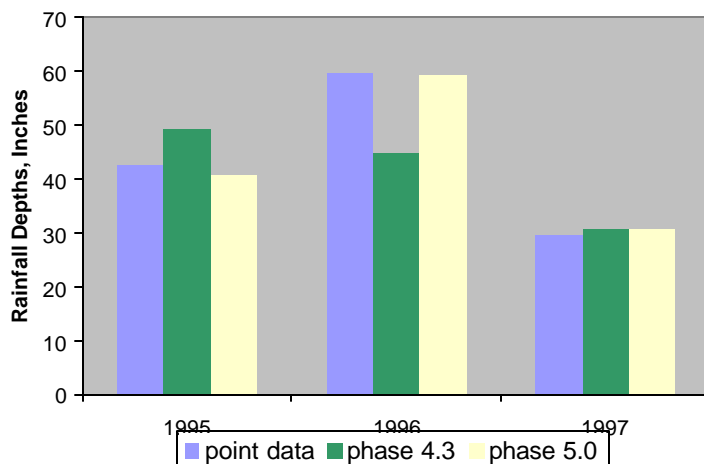


Figure 4. Annual rainfall depths comparison.

The same test was performed on the monthly basis, and values from the phase 5.0 precipitation model were again closer to the recorded monthly volumes than values from the phase 4.3 precipitation model Figure 5.

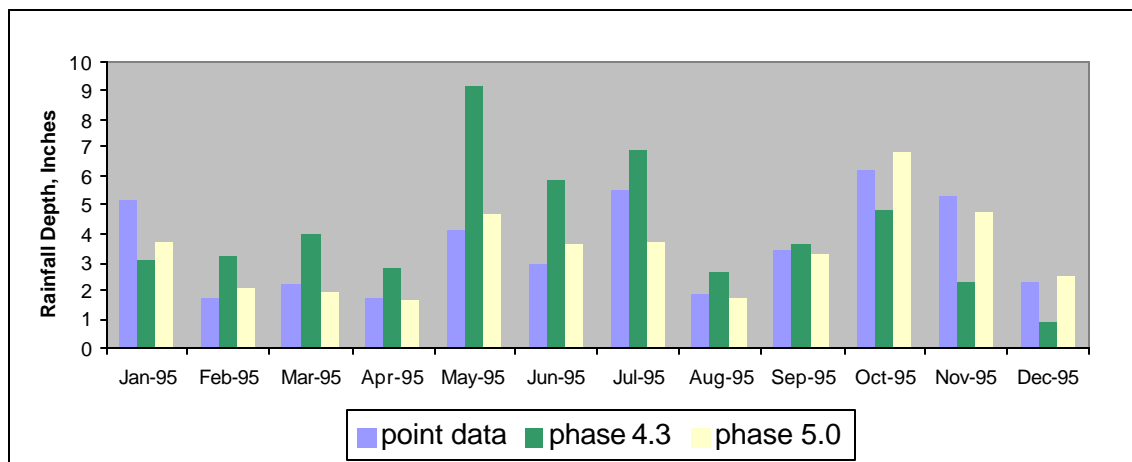


Figure 5. Monthly rainfall depths. Comparison for 1995.

Tests on temporal distribution were also performed, and the recommendation for temporal disaggregation was to use the proportions of hourly precipitation from the station with the closest daily volume within a radius of 5000 km.

The hydrological application in the Gunpowder basin indicated that the phase 5.0 had a better correlation coefficient than the simulation with data from the phase 4.3 as observed in Figure 6 and Figure 7.

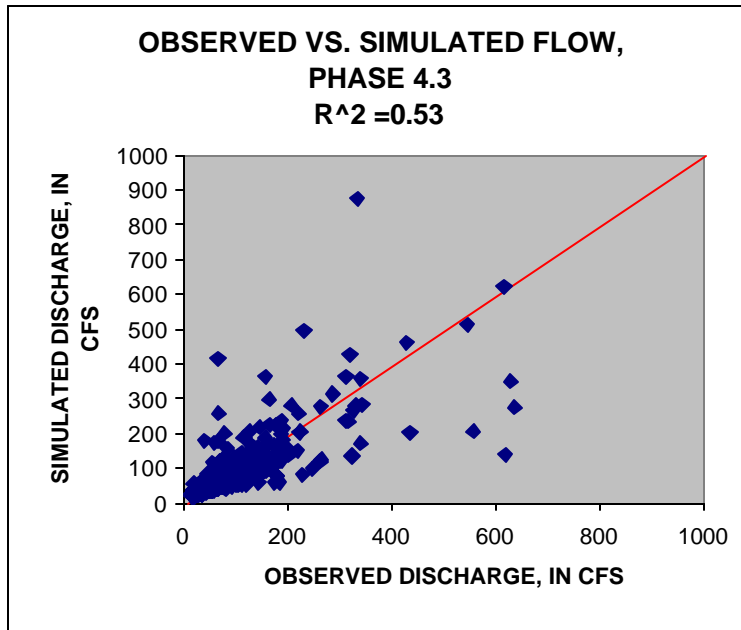


Figure 6. Log-Log of the observed vs. simulated discharge using data from the phase 4.3 precipitation model.

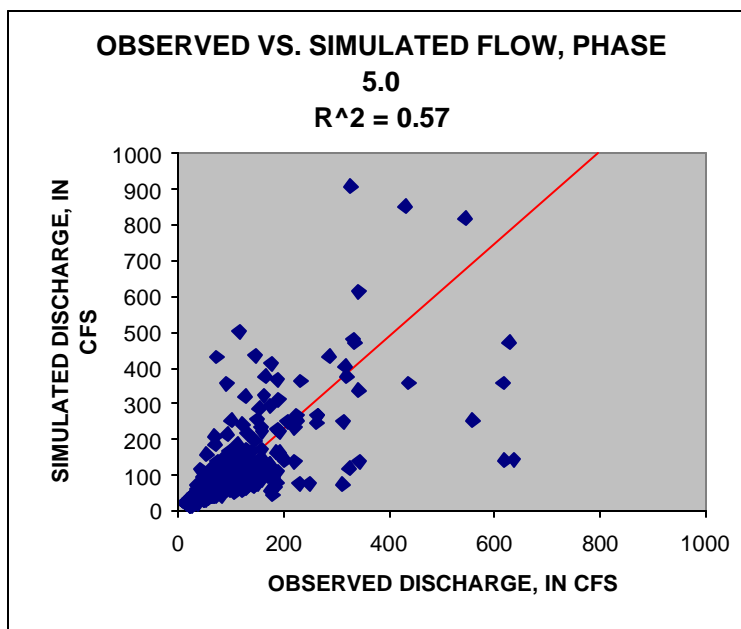


Figure 7. Log-Log of the observed vs. simulated discharge using data from the phase 5 precipitation model.

Although the difference in the correlation coefficient values were not statistically significant, the annual and monthly precipitation depths were significantly better in the phase 5 than in the phase 4.3 precipitation model.

Plans for Next Quarter

1. Identify simulated streams in the Coastal Plain region and gather regional curve data from the US Fish & Wildlife Service and the North Carolina State University for the development of geomorphic regressions.
2. Run stream channel regression equations for all gaged and ungaged reaches.
3. Calculate channel roughness coefficient for all reach segments.
4. Compare observed and estimated values of channel roughness.
5. Generate FTABLEs.
6. Compare observed stage/discharge values from gaged sites to stage/discharge values in the associated FTABLE.
7. Identify and address reach segments where this process does not work.
8. Rerun the precipitation model for the entire Potomac basin and build the time series - WDM files.

References

Tamara L. McCandless and Richard A. Everett, "Maryland Stream Survey: Bankfull Discharge and Channel Characteristics of Streams in the Piedmont Hydrologic Region", March 2002, US Fish & Wildlife Service, CBFO-S02-01.